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Comparison of Selected Operational Capabilities of Fifty-four Geographic Information Systems

Federation of Rocky Mountain States, Inc, Fort Collins, CO

Prepared for

Fish and Wildlife Service, Fort Collins, CO Western Energy and Land Use Team

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Biological Services Program

FWS/OBS-77/54
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COMPARISON OF SELECTED OPERATIONAL CAPABILITIES OF FIFTY-FOUR GEOGRAPHIC INFORMATION SYSTEMS

Interagency Energy-Environment Research and Development Program
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The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which have an impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on natural fish and wildlife resources, particularly with respect to environmental impact assessment.

2. To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major land and water use changes.

3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process, to prevent or minimize the impact of development on fish and wildlife. Biological Services research activities and technical assistance services are based on an analysis of the issues, the decisionmakers involved and their information needs, and an evaluation of the state-of-the-art to identify information gaps and determine priorities. This is a strategy to assure that the products produced and disseminated will be timely and useful.

Biological Services projects have been initiated in the following areas:

Coal extraction and conversion

Power plants

Geothermal, mineral, and oil shale development

Water resource analysis, including stream alterations and western water allocation

Coastal ecosystems and Outer Continental Shelf development.

Systems and inventory, including National Wetlands Inventory, habitat classification and analysis, and information transfer

The Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams which provide the Program's central, scientific and technical expertise, and which arrange for contracting of Biological Services studies with States, universities, consulting firms, and others; Regional staff who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities who conduct inhouse research studies.

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16. Abstracts

The report compares selected operational capabilities of 54 existing computer software systems and geographic data bases. This task was performed as part of a two-year project to develop a similar system for the U.S. Fish & Wildlife Service, to accept, store, manipulate and output spatially-related data.

In comparing the various geographic information systems, two sets of criteria were considered: "operational" criteria referring tot he general hardware and software characteristics of a particular program, and "functional"criteria referring to the actual logical function or tasks performed by specific software.

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DISCLAIMER

The opinions, findings, conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, nor does mention of trade names or commercial products constitute endorsement or recommendation for use by the federal governemnt.

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1.0 INTRODUCTION

1.1 Goal of Project

This project is defined and sponsored by the Western Energy and Land Use Team (WELUT) to promote more effective consideration of fish and wildlife resources in the numerous state and federal decisions concerning western land, energy, mineral and water resources.

The goal of this two year project is to develop an operational capability within the U.S. Fish and Wildlife Service (FWS) to accept, store, manipulate and output spatially related data for use in a variety of FWS programs. This includes not only the data that has been and will continue to be collected by the FWS, but also includes data available in computerized and non-computerized data files of other federal and state natural resource management agencies. This goal is to be achieved with minimal development of new computer software and minimal hardware requirements. The project will start on a prototype basis within selected test case areas and will broaden to other applications.

The primary users of this system in its developmental stages are in the Billings Area Office (BAO) of the U.S. Fish and Wildlife Service. The biologists in this office are faced with the weekly task of assessing the wildlife resource impacts of various land use changes. This project will attempt to develop simple, usable, practical tools for operational use at the regional and area office level, as well as more sophisticated tools for research users.

1.2 Description of Major Tasks of the Project

It is helpful to outline the seven major tasks of this project. This report falls within Task II.

Task I Assess the spatial data needs of three groups of users: 1) The Denver Region Six offices of FWS, 2) the Billings Area Office within Region Six, and 3) Special Projects of the Office of Biological Services. Development of a preliminary system design based on these needs.

Task II Survey, assess, and compare existing computer software systems and geographic data bases which are relevant to FWS determined needs. This may include federal, state, and private software and data bases.

Task III Develop an interim software system and test data base(s) covering the pilot test area(s). (WELUT Montana-Wyoming test area).

Task IV Benchmark test and evaluate the most promising geographic information system software as determined from Task II.

Task V Implement the selected software system on a government computer as determined by FWS-WELUT.

Task VI Test and debug the new FWS-WELUT geographic information system and document it with both users and technical manuals.

Task VII Train FWS personnel in the applications, use and limitations of the system. This task will be on-going throughout the project.

1.3 Purpose

This report presents the results of the initial evaluation of the "off the shelf" computer software for possible inclusion in the FWS GIS. This evaluation is based on three previous efforts:

1) User Needs Assessment (Report 1.1)
2) General GIS System Description (Report 1.2)
3) Detailed GIS System Description (Report 2.1)

To summarize, based on the user needs assessment, the GIS is visualized as containing four major sub-systems. Each sub-system in turn is comprised of other modules (Figure 1). The FWS GIS must operate under certain operational constraints and must perform certain logical functions (Report 2.1). This initial evaluation of existing GIS software is based primarily on operational criteria, such as programming language and documentation. However, functional criteria are also considered. For example, suppose a piece of software were not operational on a favored computer, but the function it performs is vital to meet FWS requirements. This software package then receives a higher rating.

2.0 THE CRITERIA USED IN EVALUATION

As mentioned above, two sets of criteria were considered. "Operational" criteria refer to the general hardware/software characteristics of a particular program. "Functional" criteria refer to the actual logical function(s) or tasks performed by a piece of software. The initial evaluation and selection process is based primarily on the operational criteria. A second evaluation will be made based on the functional capability criteria alone. This two-phased selection process is being followed to allow the large number of GIS programs to be systematically evaluated.

Figure 2 presents the operational criteria for the FWS GIS. The definition of operational criteria was constrained by the fact that FWS (Region 6) must use either a Data General Eclipse or a CDC CYBER for a mainframe. FORTRAN was selected as the favored language because it is universally applied an generally understood in the GIS user community. The remainder of the operational criteria are based on FWS user specifications, good programming practices, or software transportability considerations.

The functional criteria which define required capabilities of the system (ability to input, composite, display data, etc.) are listed in Appendix A. These criteria have not yet been applied to these 54 systems, but will be used in a later step.

3.0 THE SYSTEMS EVALUATED

Concurrent with the user needs assessment and preliminary system design, documentation was gathered on existing GIS. For the purpose of this project, a system is defined as any piece of GIS software that performs more than one unique GIS function, such as data input, data analysis, and data display. The reason for this division is to separate single purpose software from multi-purpose GIS software in order to keep the number of systems to be evaluated as small as possible.

References to different systems came from many sources, including IGU (1975), McDonald (1975), Power (1975), and from personnel experience of the staff. For each system, documentation on actual system applications, users manuals, and technical manuals were obtained where available. The documentation search ended July 15, 1977, after four months, and nearly 85 different systems had been defined. These 85 geographic information systems are listed in Table 1. Of these 85, we obtained sufficient documentation to write 2 to 5 page standardized descriptions on 52 systems. Figure 3 presents a condensed version of the standardized description. The standardized descriptions were used as the information base for evaluation.

4.0 EVALUATION PROCEDURE

Only the 52 systems with sufficient documentation were further considered in the process, since undocumented software generally are not portable.

A set of the standardized system descriptions were prepared and distributed to several technical and managerial staff. Each individual was given a week to read and relate each system to first, the operational, and second, the functional criteria. Based on this evaluation each individual decided whether a system should be: 1) considered further for adoption, 2) considered only for functions or algorithms, or 3) dropped from further consideration.

At the end of the week, the group convened to compare the results of individual evaluations. Each system was discussed and voted on. Table 2 is a summary table of the results of the evaluation. The information presented in Table 2 represents summary characteristics from available documentation. In some cases, local modifications to the systems will result in characteristics different from those shown in this summary table. The summary should then be viewed as an overview of some of the geographic information systems. More detailed systems descriptions are available from the contact person in column 2 of the table.

Originally, the evaluation was intended to be purely objective, quantitatively based on the operational criteria. However, in reality, this initial selection process was both an objective and subjective decision process, due to trade-offs in the operational and functional characteristics of each system. A quantitative number could not be derived that would adequately reflect all the components of the evaluation process. Thus the final decision was one of professional judgement, conditioned by the criteria contained in Figure 2.

5.0 SUMMARY AND FINDINGS

Based on the initial evaluation, eleven complete systems and pieces of fourteen systems have been selected for further study. The eleven complete systems are:

COMPIS	- Comarc Corporation
CRIS	- BLM
CMS-II	- Department of Commerce
EPPL 4	- Minnesota Land Management Information System
GIMMS	- University of Edinburgh, Scotland
LUMAD	- USGS Geography Program
ORRMIS	- Oak Ridge National Lab
PLUSX - PLUS2	- University of Western Ontario
WRIS	- U.S. Forest Service
CONGRID	- U.S. Forest Service
The SAG SYSTEM	- Fish and Wildlife Service

The fourteen partial systems are indicated in Table 2. The partial systems vary from complete modules to algorithms.

6.0 NEXT EVALUATION STEPS

Both the eleven complete systems and the nineteen "selected functions" will be analyzed in more detail.

Actual systems architecture and program code will be studied to determine the transportability, programming techniques, and efficiencies for each system. The pieces of software that rank highest in these evaluations will then form basic building blocks for the FWS GIS.

Figure 1

PRELIMINARY GEOGRAPHIC INFORMATION SYSTEM DESIGN

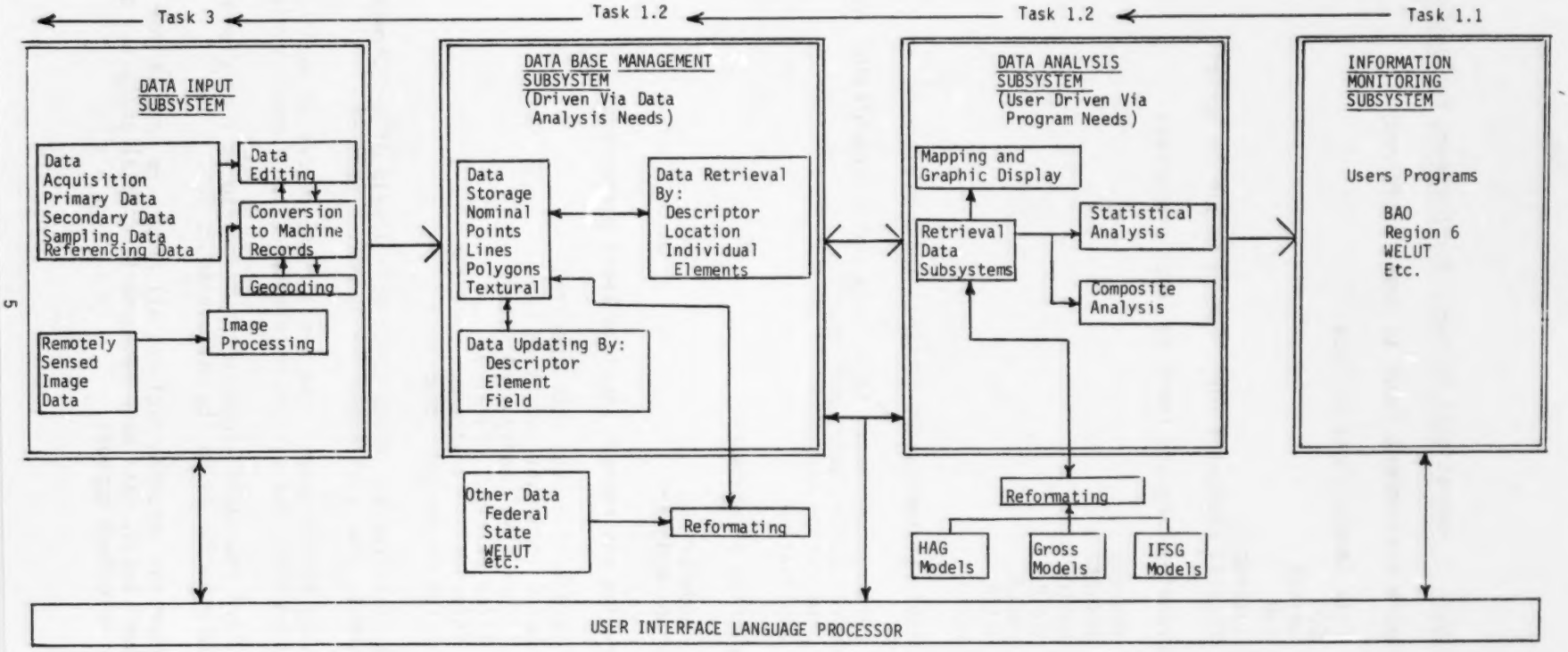

Figure 2 Operational Criteria for Software Evaluation

A. Hardware environment (most to least preferred)

1. Data General/Nova Eclipse
2. CDC
3. UNIVAC
4. IBM
5. Interdata
6. Digital Equipment Corp. PDP II or PDP 10 series

B. Programming Language (most to least preferred)

1. FORTRAN IV
2. FORTRAN V
3. BASIC
4. COBOL
5. PASCAL
6. ALGOL
7. other

C. Available Documentation (most to least preferred)

1. application, user, technical, and implementation instructions
2. application, user, and technical
3. application and user
4. application

D. Modularity of software

yes modular
no non-modular

E. Operation environment (most to least preferred)

1. interactive (end user operated)
2. batch (end user operated)
3. interactive (analyst operated)
4. batch (analyst operated)
5. interactive (programmer operated)
6. batch (programmer operated)

F. Cost of software - Given comparable levels of performance between programs, the least expensive is most preferred.

G. Machine independence - the greater the degree of machine independence of a program, the more it is preferred for further evaluation.

H. Any "off the shelf" program requiring exotic libraries will receive a low priority as to its usefulness to FWS.

I. Whether the software included all necessary modules for a "complete system" input, data base management, spatial analysis, output, and user interface support.

Figure 3

SYSTEM ASSESSMENT

PROGRAM DESCRIPTIONS

1. Identification (name of program--acronym and extended name)

2. Purpose (first paragraph is a general description; succeeding paragraphs, if required, are more specific; they cover method used, unusual features, range of applicability, and related programs). Use space provided on this page and continue on the back of this page if additional space is required.

3. Sample Output Is there sample output?

4. Programming Basis and Operating Information

   a. Mode of usage:

      batch
      interactive
      real time
      other (specify)

      Program-use interface:

      end user operated
      programmer operated
      other (specify)

   b. Operative Computer(s)

      1. computers on which this program is currently running:
      2. other computers on which program should run with little or no modification:
      3. Comments on transferability:

   c. Fast Memory and Peripherals Required:

core	disk(s)	
word size	plotters(s)	(specify type)
tape(s)	terminals	(specify type)

   d. Programming Language(s):

      languages in which program is written:

   e. Operating System Required:

   f. Data Files Used:
      (Indicate whether any special data files are required. If so, indicate name, description, storage mode, and type of geocoding).

5. Program Evaluation Information

   a. Number of source statements
   b. Compilation time

c. Any special libraries required
d. Execution time (specify criteria basis, such as number of variables, options, number of data points, etc.)

6. Origin of Program

a. Author name
b. Organization
c. Is program supported?
If yes, specify support organization and type of support provided.
d. Documentation

7. Availability

a. Contact for acquisition (name and address)
b. Acquisition conditions (indicate costs where applicable)

lease	handling mailing only
exchange	royalty payment
free of charge	specific users only
subscription fee	distribution for everyone

c. Materials available in installation package:

program manuals	sample input
source code	sample output
object code	

d. Status of release: _____tested _____evaluated

8. Description Prepared

Name
Organization
Title
Date

TABLE 2
LIST OF 85 EXISTING GEOGRAPHIC INFORMATION SYSTEM

System Acronym	Agency, University, or Business Organization	System Acronym	Agency, University, or Business Organization
ADAPT	W.E. Gates & Associates	GRID	E.S.R.I.
AUTOMAP	E.S.R.I.	GRID	Harvard
BNDRYNT	Univ. of British Columbia	IBIS	Cal Tech, Jet Propulsion Lab
CADDS	Computer Division, Inc.	IMAGE	Univ. of Saskatchewan
CAM	C.I.A.	IMGRID	Harvard University
CART 8	Instronics	INFORM	U.S. Forest Service
CGIS	Canada Land Inventory	JURIS	University of Michigan
CLARI	Colo. State University	LCO-ELF	(from secondary reference)
CMS I	U.S. Dept. of Commerce	LEMS	State of Louisiana
CMS II	FRMS	LIMAP	State of South Dakota
COMLUP	U.S. Forest Service	LUAS	NASA
COMPIS	Comarc Design Systems	LUIS	Univ. of Massachusetts
CONGRID	U.S. Forest Service	LUMAD	U.S. Geological Survey
CONPLOT	Defense Mapping Agency Topo Labs	LUMIS	Cal Tech
CRIS	Bureau of Land Management	LUMP	Univ. of California
ECOMAP	Colo. State University	MAG I	State of Maryland
EPPL	Earth Systems Research, Inc.	MAP/MODEL	Univ of Oregon
EPPL-2	Earth Systems Research, Inc.	METLAND	Univ. of Massachusetts
EPPL-4	State of Minnesota	MIADS-2	U.S. Forest Service
GADS	I.B.M.	MIDAS	State of Maine
GELO	Soil Conservation Service	MLMIS	State of Minnesota
GIM	U.S. Forest Service	MOSAIC	U.S. Forest Service
GIMMS	Univ. of Edinburgh, Eng.	MSDAMP	University of Iowa
GMAPS	Colo. School of Mines	NARIS	University of Illinois
GRASP	Univ. of Wisconsin	NORMAP	Univ. of Lund, Sweden

TABLE 2 (Cont.)

System Acronym	Agency, University, or Business Organization
NRIS	Raytheon, Corp.
OASIS	National Oceanic and Atmospheric Adminstration
ORRMIS	Regional Environmental Systems Analysis Program, Oak Ridge
PIOS II	E.S.R.I.
PLANMAP	State of Washington
PLOT	U.S. Forest Service
PLUS/2	University of Western Ontario
PLUS X	University of Western Ontario
POWER	Virginia Polytechnic Institute
PTOLEMY	Batelle Labs
RAMP	U.S. Forest Service
RAP	NASA
READ	State of North Dakota
SACARTS	Defense Mapping Agency Topo Labs
SAG	U.S. Fish and Wildlife Service
SNAPS	Defense Mapping Agency Topo Labs
SPIT	Soil Conservation Service
STOPIN	Engineering Topo Labs, U.S. Army
STORET	Environmental Protection Agency
TIGRIS	National Parks Service
TMSFRG	Swedish government
TOPAS	U.S. Forest Service
TRAS	University of Massachusetts
TVA	Tennessee Valley Authority
UDIS	(from secondary reference)
WRAP	Tennessee Valley Authority
WRIS	U.S. Forest Service

TABLE 2

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation*	Program Operation Environment	Exotic Libraries?	Acquisition mode	Geographic Data Type	Required Memory	FRMS Decision
ADAPT	W.E. Gates & Assoc. 1515 Cincinnati - Batavia Pike Batavia, Ohio 45103 (513)732-1212	IBM 370 or PDP 15	FORTRAN	2	Batch & Interactive	No	unknown	IRREGULAR Triangular GRID	IBM= up to 200K bytes	selected functions
AUTOMAP II	E.S.R.I. 380 New York St. Redlands, CA 92373 (714)793-2853	IBM 360	FORTRAN	3	Batch	No	one time lease	Cell	240 K bytes	No
BNDRYNT	IBM version - David Douglas Ministry of Urban Affairs Ottawa, Canada D.G. version - Carl Reed 1 Drake Pk., #142 333 W. Drake Road Ft. Collins, CO 80521	IBM 360 Data General Nova 840	FORTRAN	3	Batch & Interactive	No	handling/ mailing	line and polygon	IBM= approx 120K bytes DG= 32 K bytes	selected functions
CADDS/3	COMPUTERVISION 201 Burlington Rd. Bedford, MA 01730 1-617-275-1800	Data General, Nova 1200, Eclipse	98% FORTRAN 2% Assembler	2	Interactive	No	purchase agreement	Arc, polygon, point	128 K bytes	selected algorithms
	1. technical, users, installation instructions, & application 2. application, users, technical 3. appl., user 4. application									

*see criteria sheet for description of level of documentation.

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Acquisition mode	Geographic Data Type	Required Memory	FRMS Decision
CAM	IBM version: U.S. Dept. of Comm. N.T.I.S. 5285 Port Royal Rd. Springfield, VA 22151 CDC version: Dept. of Geog. SUNY Buffalo 4224 Ridge Lea Rd. Amherst, NY 14226	IBM 360 CDC 6400	FORTRAN	2	Batch	No	handling/ mailing	point, line, polygon	IBM= 250 K bytes CDC= 150 K words	selected functions
CART-8/ INTERMAP	Instronics, Ltd. 171 Neil Avenue Stittsville, Ont. Canada KOA 3GO	PDP 8e PDP 11	Assembler, some FORTRAN	1	Interactive	No	General lease	symbol, point, line, polygon, alpha	32 K bytes	selected algorithms
CGIS	Dick Switzer Land Management Info. Systems Lands Directorate Environ. Canada Ottawa, Ontario	IBM 360 IBM 370	PL-1/X (maj.), Assembler	2	Batch and Interactive	unknown	unknown	line	300-1000 K bytes	selected algorithms
CMS-I	U.S. Dept. of Commerce Economic Develop-ment Admin. Washington, D.C.	UNIVAC 1108 CDC 6400	FORTRAN	1	Batch	No	handling/ mailing	cell	250 K bytes	No
CMS-II	Federation of Rocky Mtn. States Suite 300-B 2480 W. 26th Ave. Denver, CO 80211	IBM 360/370 CDC-CYBER	COBOL + FORTRAN IV	1	Batch	No	handling/ mailing	input=polygon or cell; analysis=cell	260 K bytes	Yes

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition mode	Geographic Data Type	Required Memory	FRMS Decision
COMPIS	COMARC Design Systems 575 Union Blvd., Suite 102 Lakewood, CO 80228 303-988-5830	Data General Eclipse C-330 or S-230	FORTRAN	1	Interactive	No	purchase (w/ options) or lease	input=line, point, polygon analysis=line, point, polygon, cell	64 K bytes	Yes
COMLUP	U.S. Forest Service Fort Collins Computer Center 3825 E. Mulberry Ft. Collins, CO 303-493-5800	CDC 3100 UNIVAC 1110	FORTRAN	3	Batch - some Interactive	No	handling/ mailing	input=arc; storage=polygon; analysis=cell	CDC= 32K words	selected functions
CONGRID	Richard Hokans Univ. of Georgia School of Forest Resources Athens, Georgia	IBM 360/370 UNIVAC 1108	FORTRAN	2	Interactive	No	handling/ mailing	cell	IBM= 250 K bytes	Yes
CRIS	Bob Green BLM Den. Fed. Center Denver, CO	CDC CYBER	FORTRAN	3	Batch and Interactive	No	handling/ mailing	input=polygon analysis= polygon, cell	unknown	Yes
ECOMAP	Dr. Charles Bonham College of Forestry & Nat.Resources Colo. State Univ. Ft. Collins, CO 80521	CDC 6400 CDC CYBER 172	FORTRAN	3	Batch	No	handling/ mailing	cell	100 Kwords	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition mode	Geographic Data Type	Required Memory	FRMS Decision
EPPL2	Earth Systems Research, Inc. 3402 Univ. Ave.,SW Minneapolis, Minn. 55414 612-339-5109	CDC 6400	FORTRAN	3	Batch	No	unknown	cell	60-150 K words	No
EPPL4	MLMIS	CDC 6400	FORTRAN	3	Batch	No	unknown	cell	60-150 K words	Yes
EZ-MAP	Dr. Charles Bonham College of Forestry & Nat. Resources C.S.U. Ft. Collins, CO 80521	CDC 6400	FORTRAN	3	Interactive	No	handling/ mailing	cell	65 K words	No
GIMMS	PLU Document Librarian U. of Edinburg Rm 3217, JCMB Kings Bldg. Mayfield Rd. Edinburg, Scotland	IBM 360 ICL 4175	FORTRAN	2	Batch and Interactive	No	handling/ mailing	Points, lines, polygons	IBM= 190 K bytes	Yes
GMAPS	K. Turner Colo. School of Mines Golden, Colorado	DEC-10	FORTRAN	4	Interactive	No	unknown	cell	unknown	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition mode	Geographic Data Type	Required Memory	FRMS Decision
GRASP	Dr. William Gates Inst. for Environ. Studies U. of Wisconsin	UNIVAC 1108	FORTRAN and Assembler	3	Interactive	IODR-file manager at Wisconsin	handling/ mailing	cell	unknown	selected functions
GRID	Lab. for Computer Graphics & Spatial Analysis Grad. School of Design Harvard Univ. 520 Gund Hall 48 Quincy Street Cambridge, MA 02138 (617)495-2526	IBM 360 Burroughs 6700	FORTRAN	3	Batch	No	Purchase	cell	IBM= 150 K bytes	No
IBIS	Nevin Bryant Jet Propulsion Lab Cal Tech Pasadena, CA 91103	VICAR Image System	FORTRAN	3	Interactive	VICAR display software	unknown	polygon-Landsat (cell)	unknown	No
IMAGE	Dr. A.R. Boyle Dept. of Elec. Engineering U. of Saskatchewan Saskatoon, Saskatchewan, Canada	DEC PDP 8-e	Assembler	2	Interactive	No	purchase	point, line, polygon, alpha	32 K bytes	selected algorithms
IMGRID	Lab. for Computer Graphics & Spatial Analysis, Grad. Sch. of Design, Harvard 520 Gund Hall 48 Quincy St. Cambridge, Mass. (617)495-2526	IBM 360	FORTRAN	3	Batch	No	small purchase fee	cell	32 K bytes	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
IRIS/ NARIS	Peter Allsberg Center for Adv. Computation U. of Illinois Urbana-Champaign Urbana, IL 61801	Burroughs 6700	ALGOL	3	Interactive	No	Handling/ mailing	Irregular grid	unknown	selected algorithms
LEMS	Rockwell International Space Division	UNIVAC 1108	FORTRAN, COBOL, Assembler	2	Batch	No	unknown	points, lines, polygons, text	unknown	No
LUAS	NASA Nat. Space Tech. Labs Bay St. Louis, Miss. 39520	UNIVAC 1108 CDC-CYBER	FORTRAN IV	2	Batch	No	handling/ mailing	input=cell, polygon; analysis=cell	UNIVAC= 240 K bytes CDC= unknown	selected functions
LUMP	Dr. R. Johnson Div. of Envir. Studies U. of Calif. Davis, CA	Burroughs 6700	ALGOL	3	Batch and Interactive	No	subscription fee	cell	unknown	No
LUMAD	Dr. J. Anderson Geog. Program USGS, Nat. Center Reston, VA	IBM 370 D.G. Nova 840	FORTRAN	2	Batch and Interactive	No	handling/ mailing	input=line; analysis=cell, polygon	Nova= 64 K bytes IBM= 320 K bytes	Yes
LUMIS	C. Paul Jet Propulsion Lab Cal Tech Pasadena, CA 81103	IBM 360	FORTRAN + ALGOL	3	Interactive	No	unknown	line & cell	unknown	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
LIMAP	S. Dakota State Planning Bureau State Capitol Bldg. Pierre, SD 57501	IBM 360/370	FORTRAN	3	Batch	No	unknown	Landsat	unknown	No
MAGI	E.S.R.I. 380 N. York St. Redlands, CA 92373 (714)793-2853	IBM 360	FORTRAN	2	Batch	No	project basis	cell	unknown	No
MAP/ MODEL	Bur. of Governmental Research & Service U. of Oregon Portland, OR	IBM 360/370	FORTRAN & PL/1	3	Batch	No	handling/ mailing	polygon	113 K bytes	selected algorithms
MIADS/2	Computer Services Librarian Pacific SW Forest & Range Experiment Station P.O. Box 245 Berkeley, CA 94701	IBM 7040, IBM 7090, UNIVAC 1110	FORTRAN, MAP	3	Batch	No	handling/ mailing	alpha, cell	IBM= 64 K bytes	No
MIDAS	State of Maine	RCA Spectra 70	FORTRAN, Assembler	3	Batch	Yes	unknown	alpha, line, point, polygon	130 K bytes	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
MLMIS (see also EPPL)	Allen Robinette Minn. State Planning Ofc., Capitol Square Bldg. 550 Cedar St. St. Paul, MN 55101	CDC 6400	FORTRAN	2	Batch	No	unknown	irregular cell ¼,¼ section PLS	unknown	No
MOSAIC	SEAM, USDA Forest Service 145 Grand Ave. Billings, MT 59102	CDC 7600, IBM 370, UNIVAC 1110	FORTRAN	2	Batch	No	Handling/ mailing	Digital terrain (point)	I3:1= 240 K bytes	Selected features
MSDAMP	Dr. K. Dueker Inst. of Urban & Regional Research U. of Iowa Iowa City, IA 52242	IBM 360	FORTRAN	3	Batch	No	handling/ mailing	cell	unknown	selected features
NORMAP	S. Nordbeck Dept. of Geog. U. of Lund Lund, Sweden	UNIVAC	FORTRAN & ALGOL	3	Batch	No	unknown	line	unknown	selected functions
NRIS	Raytheon Corp. Autometric Corp.	IBM 360-370	FORTRAN	2	Batch	No	handling/ mailing	input=line; analysis= line, polygon.	unknown	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
ODYSSEY (not yet a system)	Lab. for Computer Graphics & Spatial Analysis Grad. School of Design Harvard Univ. 520 Gund Hall 48 Quincy St. Cambridge, MA 02138 (617)495-2526	PDP-10, CDC, IBM	FORTRAN IV	N/A	Interactive	No	unknown	polygon, line	unknown	n/a
ORRMIS	Richard Durfee ORNL Regional Urban Studies Dept. P.O. Box X Oak Ridge, TN 37830 (615)483-8611	IBM 360-370	FORTRAN - 1 assembler	2	Batch	No	handling/ mailing	hierarchial cell	210 K bytes	Yes
PIOS-II	Comprehensive Planning Organization San Diego, CA	Burroughs 6700	FORTRAN	2	Batch and Interactive	No	Small purchase fee	polygon + cell	76 K bytes	selected functions
PLUS	Dr. M. Goodchild Dept. of Geog. U. of W. Ontario Ontario, Canada	IBM 360, PDP11 CDC CYBER 173	FORTRAN	2	Batch and interactive	No	unknown	storage=polygon; analysis=cell	depends on computer	Yes
POWER	D. Clair Jones Dept. of Fisheries & Wildlife Sci. VA Polytechnic Institute Virginia	IBM 370	FORTRAN, PL/I	2	Batch	No	handling/ mailing	cell	up to 330 K bytes	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documen-tation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
PTOLEMY	E.R Hill Battelle Pacific NW Laboratories Richland, VA 99352	PDP 11/45	FORTRAN IV	3	Interactive	Yes -Vetor General	unknown	polygon	64 K bytes	selected functions
RAP	Gary Rockwood Bureau of Economic & Bus. Research College of Bus. U. of Utah	UNIVAC 1108	FORTRAN	3	UNIVAC Denmark mode	No	handling/ mailing	storage= point,arc, polygon. analysis=cell	unknown	No
REAP*	Dr. A. William Johnson REAP Director 316 N. Fifth St. Room 521 Bismark, ND 58505	←			UNKNOWN			→		unsure
SAG	Jack Gross Ecol. Modelling Team, FWS One Drake Park Suite 260 333 W. Drake Rd. Ft. Collins, CO	CDC 6400	FORTRAN	2	Interactive	No	unknown	polygon	50 K words	Yes
STOPIN	A. Gunther U.S. Army Engineer Topog. Lab Ft. Belvoir, VA	CDC 6600	FORTRAN	2	Batch and interactive	No	handling/ mailing	alpha	75 K words	No

System	Contact	Hardware Environment (CPU)	Programming Language	Level of Documentation	Program Operation Environment	Exotic Libraries?	Normal Acquisition Mode	Geographic Data Type	Required Memory	FRMS Decision
SYMAP	Lab. for Computer Graphics & Spatial Analysis, Graduate School of Design, Harvard Univ. 520 Gund Hall 48 Quincy St. Cambridge, MA 02138 (617)495-2526	IBM 360-370 CDC machines	FORTRAN	3	Batch	No	purchase	cell	IBM 75 K bytes	No
TITOPO	Peggy Morgan Data Systems Div. NPS US Dept. of Int. Washington, D.C.	IBM 370	FORTRAN	2	Batch and interactive	No	non-proprietary portions handling/ mailing	digital terrain	unknown	selected functions
TOPAS	Ft. Collins Computer Center Forest Service 3825 E. Mulberry Ft. Collins, CO 493-5800	UNIVAC 1110	FORTRAN	2	Batch and interactive	No	unknown	Digital terrain	unknown	selected functions
WRIS	Computer Services Librarian Pacific SW Forest and Range Exper. Station P.O. Box 245 Berkeley, CA 94201	UNIVAC 1110	FORTRAN, Assembler	2	Batch	No	handling/ mailing	polygon	unknown	Yes

* Need more information

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McDonald, Mary V. 1975. A Wildlife and Natural Resources Information System for Virginia. unpublished Master's thesis proposal. Dept. of Fisheries and Wildlife, Virginia Poly Tech Institute and State University, Blacksburg, Virginia.

Power, Margaret. 1975. Computerized Geographic Information Systems: An Assessment of Important Factors in Their Design Operation and Success. Center for Technology Development, Washington University. Report No. CDTDM-RCT - 75/3.

APPENDIX A
FUNCTIONAL CRITERIA FOR SOFTWARE EVALUATION

A) DATA INPUT

Required Data Types
- point (water wells)
- arc (National Wetlands Inventory data)
- polygon loop (a common mode for encoding and storing polygons - WRIS, PLOT, PIOS)
- raster (Landsat, scanner input)
- grid (a common, inexpensive method of encoding geographic data - related to raster)
- textual (information describing the above data: its accuracy, source, and other characteristics, plus bibliographies, documents.)

Format of Required Data
- ability to adjust for different scales
- the ability to transform from digitizer coordinates to a common coordinate system.
- the ability to transform from one projection to another. So far, the most commonly cited projections are Latitude-Longitude, State Plane, UTM, Lambert Conformal, and Public Land Survey (Township-Range).

Edit during Encoding
- point data editing abilities
- arc data editing abilities
- polygon data editing
- raster data editing
- textual data editing

Post Edit
- delete duplicate or unnecessary points, arcs, polygons, rasters or points in arcs and polygons (weeding).
- locate logical errors
- projection change to geographic reference system of data base
- conversion from table coordinates to data base coordinates

Operating Environment for Data Input (summary)
- ability to encode map data
- ability to encode text data
- ability to handle classified Landsat images
- ability to input a coarse level (1 encoded point per inch of line) or at a fine level (20 points per inch of line).
- ability to interactively interface with the encoding process, especially for edit purposes
- ability to display both textual and graphic data

B) DATA BASE MANAGEMENT

General Characteristics of FWS GIS Data Base Management System
- ability to support many users
- ability to support many data sets
- ability to store both small and large data sets

Data Update
- ability to add new data
- ability to delete existing data

- ability to change or modify existing data
- ability to add files
- ability to delete files

Data Retrieval
- a straight copy of a user data set
- a straight copy of a particular subject or variable
- extract data on the basis of nearness criteria
- extract data within a geographic window
- extract data on the basis of juxtaposition (selection on the basis of proximity)
- extract data on the basis of buffer zones
- extract data on the basis of contiguous spatial units having a specified quantity and quality level (clustering)

Interface to Other Agencies
- ability to re-format existing automated data to coincide with the FWS data base format
- ability to merge these data into the existing data base
- ability to supply data in various formats to an outside agency requesting data, such as habitat data

C) DISPLAY AND ANALYSIS

Data Analysis and Display - General Capabilities
- spatial analysis
- mapping and graphic display
- statistical analysis
- report generation
- modeling efforts
- measurement

Spatial Analysis
- polygon intersections and unions
- cell compositing (logical and arithmetic)
- view shed analysis
- corridor analysis (power lines, e.g.)
- spatial clustering
- spatial aggregation
- edge analysis
- slope and aspect analysis

Mapping and Graphic Display
- three dimensional surfaces
- proximal maps (cell and polygon)
- choropleth maps (cell + polygon)
- contour maps (cell + polygon)
- slope and aspect maps
- 2 variable line graphs
- 2 variable bar graphs
- dot maps (locations of water wells)
- line maps (polygonal outlines)

Statistical Analysis
- histograms (frequency counts)
- regression (multiple, step-wise)

- correlation
- cross-tabluations (bi-variate)
- classification (grouping or clustering - numerical taxonomy)

Modeling
- Dr. Gross' Oil Shale model and Big Game Population Dynamics
- Dr. King's Socio-Economic Projection model
- Land use projection model
- Habitat classifications techniques (HAG)
- In-stream flow classifications (ISFG)
- Dr. Schamberger's Project Impact Evaluation Techniques (HEP)

Measurement
- points
- lines (arcs)
- polygons
- raster and grid
- textual

Report Generation (Table Generation)
- allow the user to supply labels for the report (table)
- formatted to: line printers (132 columns), teletyper (80 columns), CRT's (80 columns)
- allow the user to supply relevant descriptive information (source, figure number, and so forth) to be added to the table to make it suitable for publication.
- allow the user to save a report as part of the data base (for future reference)
- provide a standard report format as a default.

Summary of Data Analysis and Display Criteria
- arc to polygon conversion
- calculation of slope and aspect from terrain data
- polygon to grid
- raster/grid to polygon
- aggregation of cells/pixels to form larger cells/pixels
- point to grid interpolation

D) LANGUAGE PROCESSOR

Language Processor
- ability to allow free format input by the user
- ability to define a query language on the basis of FWS user needs
- ability to change the query language as required by FWS users
- ability to monitor the types of queries to FWS GIS and to provide usage reports as part of a continuing feedback process to maintain an effective GIS
- ability to accept user i.d. numbers and determine: if they are valid, and what data that i.d. has access to.